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# Responses to Transit Information among Car-drivers: Regret-based Models and Simulations

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**ABSTRACT** This article investigates the use and effects of transit information among car drivers that consider transit as a mode-option in their choice set. It does so by first presenting a theoretical model of travel information use and effect, based on the integration of notions of Bayesian updating into a regret-based framework of travel choice. Subsequently, numerical simulation of the model provides insights into the mechanisms behind information use and effect in a mode-choice context where a traveler has both car- as well as transit-options in their choice set, and prefers traveling by car over riding by transit. These simulations show that the perceived value of acquiring transit information is limited by a number of factors. Furthermore they demonstrate that, even in the case where transit information is acquired, and the message is favorable to transit, its impact on mode choices will also be limited. Given these results for non-habitual car-drivers, it is suggested that for car-drivers in general (thus including the large share of habitual drivers), conservative estimates regarding the impact of transit information provision on modal shift would be realistic.

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## Introduction

It is generally acknowledged that providing travelers with relevant information on travel options has the potential to change their behavior. An increasing interest has arisen in these information effects over the last years, as is indicated by a number of policy studies on the topic (Commission of the European Communities, 2001; Dutch Department of Transport, 2002; US Federal Transit Administration, 2003; UK Department for Transport, 2004) and academic research papers (Abdel-Aty, 1996, 2001; Kanninen, 1996; Ouwersloot *et al.*, 1997, Reed *et al.*, 1997; Benjamin, 2006; Chorus *et al.*, 2006a). Some modal-shift policy initiatives have therefore included the provision of high quality travel information on transit, as the above noted policy documents illustrate. It is clear that, in order for transit information to have any effect on the modal split between private car and transit, two conditions must be met: first, the information must be acquired by current car-drivers and second, the acquired information must lead to a change in their mode-choices. However, an abundant body of literature indicates that the propensity for car-drivers to acquire transit information and adapt their mode-choice behavior in favor of transit is rather low (Aarts *et al.*, 1997; Verplanken *et al.*, 1997; Neuherz *et al.*, 2000; Lyons, 2001; Gärling *et al.*, 2001, 2002; Kreitz *et al.*, 2002; Kenyon & Lyons, 2003). A general finding in most of these studies is that this lack of willingness to acquire information and reconsider mode-choice behavior is predominantly due to the fact that car-drivers do not make their mode choices in a deliberate, conscious way, but instead appear to execute a habit: their choice set contains the car-option only, and transit options are not considered in the choice process in the first place. This leaves two important questions unanswered: first, what would be the potential of transit information for mode-choice adaptation among those travelers that do have one or more transit options in their choice set, but generally favor their private car as a transport mode? Let us denote these travelers as non-habitual car-drivers. Second, what are the determinants behind these non-habitual car-drivers' choices whether or not to acquire available information, and whether or not to adapt their (intended) mode-choices?

In order to grasp the full complexity of the way in which non-habitual car-drivers deal with the information available to them, addressing all relevant mechanisms and the way they interact with

each other, an extensive formal model of information use and effects is constructed. In order to capture the intuitive explanation that traveling may often be about avoiding negative emotions, perhaps more than about deriving a maximum level of utility, we have adopted a framework of regret-based mode choice (Loomes & Sugden, 1982, 1983). This framework is based on the following two notions: (1) a traveler may be aware of the fact that, due to uncertainty in the transport network, they may end up having chosen a mode that turned out to be less attractive than a non-chosen mode. This induces regret on the side of the traveler; and (2) this traveler anticipates this possibility of regret and aims to minimize expected regret when choosing from available modes. After having derived the model, it is applied through numerical simulations to a typical mode choice situation for the type of car-driver studied here, in order to gain insight into the influence of a variety of potential determinants behind information use and effects.

The derivation of the formal model and its illustration through a fictional mode choice situation form a contribution to the existing empirical literature on this topic in three ways: first, it presents and applies a coherent framework to describe systematically the mechanisms behind travel information use and effects. Current empirical literature on this issue, although having provided valuable insights, often lacks such a rigorous approach. Second, the article provides insight into the way non-habitual car-drivers deal with travel information, thereby implicitly establishing an upper boundary for expectations concerning the effect of such information on car-drivers in general. Finally, whereas the concept of anticipated regret as a determinant of choice-behavior is well known in such areas as microeconomics, psychology and marketing (Simonson, 1992; Inman *et al.*, 1997; Zeelenberg, 1999; Crawford *et al.*, 2002; Hart, 2005), its application in the travel behavior domain is to the authors' knowledge virtually non-existent. This article shows how the regret-concept may be applied to systematically and realistically describe travelers' behavior under uncertainty.

The second section presents the derivation of the formal model. The model is subsequently applied through numerical examples in the third (discussing information acquisition) and fourth sections (discussing the effect of acquired information). Finally, conclusions on the design of transit-information services and modal split policies are presented in the fifth section.

### **A Regret-based Model of Information Use and Effect**

This section presents a regret-based model of how travelers in general may perceive the value of travel information, and may update their

choice behavior using received messages; it draws from Chorus *et al.* (2006b). For reasons of simplicity of presentation, and without any loss of generality, we here assume the highly simplified choice situation where a traveler's choice set contains one car-option and one transit-option, and where their preferences are based on an intrinsic mode-preference (for the car-option) and the modes' travel time. Travel times of both modes may be uncertain, and a traveler may acquire travel time information for either one of the two modes in order to reduce this uncertainty. In notation: suppose that a traveler faces a choice set  $S$  of two considered travel alternatives  $Y_i$  and  $Y_j$ , for example  $i$  representing a transit option, and  $j$  a car option:

$$S = \{Y_i, Y_j\} \quad (1)$$

Each of these travel modes can be thought of as being a bundle of attributes, or in the present case, as being nothing more than one attribute, travel time  $X_i$  or  $X_j$ :

$$Y_i = \{X_i\}, Y_j = \{X_j\} \quad (2)$$

The traveler is aware of the fact that their estimates of the characteristics of the two mode-alternatives may be imprecise. Their perception  $X_i^p$  of travel time  $X_i$  may therefore be represented by a random continuous variable, having a distribution  $f_i^p(x_i)$ . Throughout this paper, the normal distribution will be adopted (although many other distributions may prove suitable for the arguments made):

$$X_i^p \sim f_i^p(x_i) = N(\hat{x}_i^p, \sigma_i^p) \quad (3)$$

These perceptions are characterized by a mean travel time  $\hat{x}_i^p$  and a standard deviation  $\sigma_i^p$ . The mean represents the traveler's 'best guess' for a certain characteristic, the standard deviation represents the perceived unreliability of that estimate. The utility of a particular state of a perceived alternative, as a function of the intrinsic mode preference and the mode's travel time, may now be expressed as  $u(x_i)$ . A traveler that is confronted with perceived incomplete knowledge about the travel times of the alternatives known to them faces an expected regret as they are not certain that a considered mode alternative  $Y_i$  will turn out to be the better of the two considered alternatives. Given this conceptualization, the regret a traveler expects to be induced,  $ER$ , by choosing alternative  $Y_i$  can now be formulated as the sum of possible realizations of states (travel times) for which the realized utility of a considered alternative  $Y_i$  is lower than that of the other known alternative  $Y_j$  or the unknown alternative  $Z$ , weighted by the probability of occurrence of these states of known and unknown alternatives and the difference between the realized levels of utility.

$$ER(Y_i) = \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} [\gamma_{ij} \cdot (u(x_j) - u(x_i))] \cdot f_j^p(x_j) f_i^p(x_i) dx_j dx_i \tag{4}$$

where

$$\gamma_{ij} = \begin{cases} 1 & \Leftrightarrow u(x_j) > u(x_i) \\ 0 & \Leftrightarrow u(x_j) \leq u(x_i) \end{cases}$$

The notion  $\gamma_{ij}$  will be used throughout this article, with varying indices, to denote the situation where the utility of the alternative represented by the first index is surpassed by the utility of the other alternative. Note here that the amount of expected regret is measured in utils. As the traveler is assumed to choose the alternative which induces the lowest level of expected regret, the following represents the expected regret induced by a choice situation:

$$ER = \min_{k=i,j} (ER(Y_k)) \tag{5}$$

Note that we have thus expressed the expected regret of the choice situation in terms of the utility of the travel alternatives under evaluation. This section has presented mathematical formulations of how expected regret may determine a traveler’s mode-choices. Based on these formulations, we will now derive formulations for the perceived value of travel time information acquisition for, say, the transit option  $Y_i$ . First, we need to specify what messages the traveler may expect when acquiring information and secondly, we need to establish the effect of received messages.

At first, it may seem somewhat strange to assume that a traveler that is uncertain about the actual value of a characteristic has expectations concerning what message to receive when asking an information service for an estimate: if a traveler knows what messages to expect when acquiring information, why should they make the effort to acquire the information at all? It should be noted, however, that it is meant here that the traveler has *some* expectations concerning the information to be received, based on their initial perceptions concerning the value of the travel time, reflected in  $X_i^p \sim f_i^p(x_i)$  and the perceived unreliability of the information service, reflected in  $f(x_i^l|x_i) \sim N(x_i, \sigma_i^l)$ . Formally, we can express the traveler’s expectations concerning travel time messages in the form of  $x_l = x_i^l$  (e.g. ‘travel time by transit equals 40 min’) to be received when acquiring information as:

$$X_i^l \sim f_i^l(x_i) = \int_{-\infty}^{+\infty} f(x_i^l|x_i^p) \cdot f(x_i^p) dx_i^p \tag{6}$$

When a traveler receives a message from the information service, they use it to update their earlier perception into a new one. While doing so, they must deal with the fact that both their initial perception concerning the mode’s travel time, as well as the message received, are only partly reliable – this is reflected in  $\sigma_i^p$  and  $\sigma_i^l$  respectively. An updating mechanism that takes into account these two sources of unreliability is that of Bayesian perception updating, where probabilities are updated using Bayes’ law. A widely used concept throughout psychological research (Edwards *et al.*, 1963; Phillips and Edwards, 1966), Bayes’ law has been recently adopted in travel demand contexts to explain updating processes concerning, for example, unreliable travel-time estimates (Kaysi, 1991; Chen & Mahmassani, 2004; Arentze & Timmermans, 2005a; Chorus *et al.*, 2006b). Under the assumption of a normally distributed initial perception of both the travel times  $X_i^p$  as well as messages received  $X_i^l$ , we can, applying Bayes’ law for continuous variables (see Edwards *et al.*, 1963), derive the traveler’s updated perception  $X_i^u$  as follows:

$$X_i^u \sim f_i^u(x_i) = N(\hat{x}_i^u, \sigma_i^u) \tag{7}$$

where

$$\hat{x}_i^u = \left(\frac{1}{\sigma_i^p}\right)^2 \cdot \hat{x}_i^p + \left(\frac{1}{\sigma_i^l}\right)^2 \cdot x_i^l / \left(\left(\frac{1}{\sigma_i^p}\right)^2 + \left(\frac{1}{\sigma_i^l}\right)^2\right) \tag{8}$$

$$\sigma_i^u = \sqrt{(\sigma_i^{p^2} \cdot \sigma_i^{l^2}) / (\sigma_i^{p^2} + \sigma_i^{l^2})} \tag{9}$$

The assumption of normally distributed perceptions is often made, and often criticized for being a less valid representation of perceptions from a behavioral point of view (Bonsall, 2001). However, the assumption is non-critical for the argument made here, and is only made for reasons of simplicity: the normal distribution can be replaced by other distributions, as long as these are conjugate priors – that is, priors that are conjugate to the distribution representing the perceived unreliability of the information service. Note that, completely in line with the intuitive explanation, the more reliable the information service is believed to be (i.e. the lower is  $\sigma_i^l$ ), the more the updated perception resembles the message that is received through the information service. Note also that the more reliable the information is believed to be, the more confidence the traveler will have in their updated perceptions (reflected in a lower  $\sigma_i^u$ ). These notions are key to the reduction in expected regret that may occur through acquiring information.

It is important to note that the expected regret of the mode for which travel time information is acquired may be influenced by a received message in several ways. First, due to the message received, the traveler’s best estimate for the alternative’s travel time may be altered,

which directly leads to an increase or a decrease in expected regret that may be induced by the alternative (take for example the traveler who finds out that the travel time of a mode being considered is twice the normal travel time, due to an incident). Second, as the confidence in their estimate for some mode's travel time increases due to the reception of a message, or in other words as the spread of the perception decreases, the tails of the distribution reflecting this perception is less likely to interfere with the utility distributions of other alternatives, leading to changes in expected regret. Next to these aspects that refer to the expected regret of the alternative a message is received for, the expected regret of an entire choice situation may be diminished by receiving an estimate for some characteristic, as the traveler is given the possibility to capitalize on the improved accuracy of their choice: even the perspective of possibly receiving a disappointing message may reduce the regret that is expected to remain in the choice situation, as the traveler knows that, based on the received message, they have the possibility to not choose the alternative for which the disappointing message was received.

Based on the above conceptualization of what messages may be expected to be received when asking an information service for an estimate for the travel time of alternative  $Y_i$ , and of what may be the expected effect of such a received message in terms of perception updating, the expected regret that is perceived to remain after having asked the information service for an estimate concerning this characteristic for  $Y_i$  can now be formulated. For every message that may be expected to be received through the information service, weighted by the probability of receiving  $f_i^j(x_i)$ , an updated perception  $f_i^u(x_i)$  is formed using Bayes' rule, taking into account the traveler's beliefs about the level of reliability of their initial estimate and that of the information service. This updated travel time perception is subsequently used to re-evaluate the choice situation. Thus, the expected regret of the alternative travel time information is acquired about,  $ER^+(Y_i)$ , can be written as:

$$ER^+(Y_i) = \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} [\gamma_{ij} \cdot (u(x_j) - u(x_i))] \cdot f_j^p(x_j) f_i^u(x_i) dx_j dx_i \quad (10)$$

The traveler's expectations of regret induced by the choice situation as a whole, based on the notion that the traveler anticipates, and aims to minimize, expected regret, may be formulated as follows:

$$ER^+ = \int_{-\infty}^{+\infty} \left[ \min \left\{ \left( \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} [\gamma_{ij} \cdot (u(x_j) - u(x_i))] \cdot f_j^p(x_j) f_i^u(x_i) dx_j dx_i \right), \left( \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} [\gamma_{ji} \cdot (u(x_i) - u(x_j))] \cdot f_i^u(x_i) f_j^p(x_j) dx_i dx_j \right) \right\} \times f_i^l(x_i) dx_i \right] \quad (11)$$

Now we can write the perceived value of acquiring travel time information, *PIV*, as the anticipated difference in expected regret induced by the choice situation before and after the acquisition of information:

$$PIV = ER - ER^+ \quad (12)$$

Note that we have thus expressed the value of information in terms of the utility of the travel alternatives under evaluation. The traveler may now be assumed to compare this perceived information value to perceived information costs, which may be composed of monetary costs and, among other things, costs in terms of time, effort and attention, and the possibility of foregoing an interesting alternative during the acquisition of information (Simon, 1978; Weibull, 1978; Shugan, 1980; Richardson, 1982). We thus assume that, should the perceived information costs outweigh the perceived value as expressed in Eq. (12), the traveler will acquire information. If this is the case, and a message  $x_i = x_i^l$  is received (e.g. ‘travel time by transit equals 40 min’), the impact on the traveler’s perceptions, utility and mode choice follows the application of Eqs (7)–(9), followed by (4) and (5). The role of information in a mode choice context may be described as follows: depending on its perceived reliability, information may lead to an *update of perception*. Depending on the relevance or utility function of the informed attribute, information that has led to an update of perception may lead to an *update of utility* for a given mode. Finally, depending on the utility for all other attributes of a given mode (a traveler’s base preference for a mode), information that has led to an update of utility for a given mode may lead to an *update of mode-choice*, or choice adaptation. Moreover, a traveler knows that this is the case before they acquire information, and thus will base their decision of whether or not to acquire information on their belief in the potential of information to update their perceptions, utilities and eventually mode choices.

Although the model presented is mathematically somewhat demanding, it presents one clear and important advantage over more ad hoc modeling approaches: it presents the perceived value of information acquisition in terms of the utility derived from the attributes of the

alternatives considered in the choice, which provides a highly straightforward and coherent interpretation of the concept of information value. Using this feature, interpretation of the absolute changes in predicted information use and its effects are meaningful for a specific choice context and specific utility function of the alternative's attributes. Predicted trends or relative changes in information use and effects, however, are even more generic, providing a meaningful interpretation for all choice-contexts where the same utility functions for attributes apply. We will exploit this latter characteristic in the subsequent sections in order to derive insights regarding the relative impacts of several determinants on the use (third section) and effects (fourth section) of transit-information among non-habitual car-drivers.

### Acquisition of Transit Information among Car-drivers: Simulations

Although it would be possible to discuss the determinants of information acquisition based directly on a discussion of the derivations made above, this would complicate things unnecessarily. We have chosen here to use a fictive, though plausible, mode-choice situation and simulate the relevant mechanisms described above as illustration. This section, as mentioned earlier, focuses on information *acquisition* among those travelers that do have the transit option in their choice set, but generally prefer traveling by car. Table 1, based on equations (4), (5), (11) and (12) shows the actual computed values referring to the figures presented in this section.

The following illustrative example of a mode choice situation is proposed: consider a car-driver that faces a trip that can be performed using car or transit. Assume they are only uncertain about the modes' travel times, which are perceived as normally distributed variables with equal means  $\mu_{car} = \mu_{trans} = 50$  and standard deviations  $\sigma_{car} = \sigma_{trans} = 10$ . In case of equal travel times, they would take the car, implying that the base utility they derive from all non-travel time related attributes of the car exceed those of transit:  $u_{car}^{base} > u_{trans}^{base}$ . We take these base preferences to take on the following values:  $u_{car}^{base} = 65$  and  $u_{trans}^{base} = 55$ . Suppose furthermore that the traveler attaches a disutility to travel time by either car or train of  $u(tt) = -\beta \cdot (tt)$  with  $\beta_{base} = 1$ . The traveler now bases their choice on the expected regret for both modes, which itself is a function of the intrinsic mode preferences and the modes' uncertain travel times. Applying Eqs (4) and (5), we can compute that in this base case  $ER_{car} = 2.14$ ,  $ER_{trans} = 12.02$  and the expected regret of the choice situation as a whole equals therefore  $ER = 2.14$ . Furthermore, assume that the traveler also knows they can acquire travel time information for the transit option using an information service, the unreliability of which is represented by  $\sigma_{trans}^{info} = 1$ . Using

these values as input for equations (11) and (12), we can compute the perceived value of information: in this base case,  $PIV = 1.10$ .

As mentioned earlier, from our model’s perspective, the role of information in a mode choice context depends on its perceived potential to update perceptions, utilities and eventually choices. We will use these three conditions to identify the determinants of information acquisition. We start with the first condition, referring to the traveler’s expectation that the information they will receive should help them *update their perceptions of modal characteristics*. As derived above (Eq. (8)), this will only be the case when the perceived reliability of the information is sufficiently high relative to the traveler’s perceived reliability of their initial knowledge. This importance of this perceived – relative – unreliability is found in several empirical studies (Polydoropoulou & Ben-Akiva, 1998; Hato *et al.*, 1999; de Vries *et al.*, 2003, Fayish & Jovanis, 2004).

It is generally known that travel information in general, and travel time information in particular, is always perceived to be unreliable to some extent. Using our conceptual model we can study how the notion of relative unreliability of transit information affects the value that a conscious traveler expects to derive from information acquisition: the information unreliability is varied from  $\sigma_{trans}^{info} \approx 0$  to  $\sigma_{trans}^{info} = 10$ , keeping  $\sigma_{trans} = 10$  constant, so that relative unreliability  $\sigma_{trans}^{info} / \sigma_{trans}$  is increased from 0 to 1, step size 0.2.

Figure 1 shows us that, as expected, such a traveler’s perception of information value decreases as the perceived relative unreliability of the

Table 1. Computed values of  $PIV$

$PIV_a$		$\beta$							
		0.5	0.75	1	1.25	1.5	1.75		
$u_{car}^{base}$	55	$\sigma_{trans}^{info}$	0	–	–	–	–	–	7.69
	59	$\sigma_{trans}^{info}$	0	–	–	–	–	–	6.01
	63	$\sigma_{trans}^{info}$	0	–	–	–	–	–	4.37
	65	$\sigma_{trans}^{info}$	0.0001	0.08	0.40	1.10	1.91	2.77	3.70
			2	–	–	1.06	–	–	–
			4	–	–	0.93	–	–	–
			6	–	–	0.81	–	–	–
			8	–	–	0.68	–	–	–
			10	–	–	0.56	–	–	–
	67	$\sigma_{trans}^{info}$	0	–	–	–	–	–	3.15
71	$\sigma_{trans}^{info}$	0	–	–	–	–	–	2.23	
75	$\sigma_{trans}^{info}$	0	–	–	–	–	–	1.43	

Note: <sup>a</sup>where:  $\mu_{car} = \mu_{trans} = 50$ ,  $\sigma_{car} = \sigma_{trans} = 10$  and  $u_{trans}^{base} = 55$

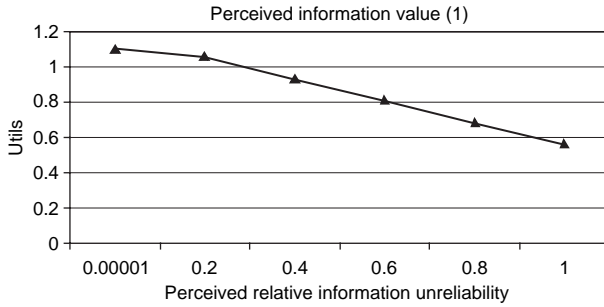


Figure 1. Influence of relative information unreliability on information value

information service increases: the traveler perceives that any information service with a high perceived relative unreliability will not be able to substantially update their initial perception of transit's travel time, and thus, by definition, will not be able to reduce the expected mistake they face. Formulated differently, the traveler knows that they will discard messages received from the information service if the source is perceived as unreliable.

An additional insight can be derived by observing that the traveler's perception of information value decreases rather slowly when the increase in relative information unreliability is small. However, as the perceived unreliability of the information starts to approach the traveler's perception of the unreliability of their own knowledge, the perceived value of acquiring the information rapidly falls with increasing unreliability. This mechanism thus stresses the paramount importance of maintaining an acceptable level of reliability of transit information services. In the light of this analysis it is also quite disturbing that car-drivers find their own knowledge concerning transit-characteristics fairly reliable (Bonsall *et al.*, 2004), although in reality they are severely biased against transit (Li, 2003; Bonsall *et al.*, 2004).

Let us now play devil's advocate and assume the highly unrealistic situation in which the transit information service is perceived among car-drivers to be completely reliable. Will this lead to a substantial usage of such information on transit among them? Assuming that the condition of perception updating has been met – so that the traveler knows that they will always be able to completely update or replace their perceptions based on the information acquired – let us examine the second condition, which states that the traveler should feel that the information that might be received may help them *update the utility they may derive from the transit option*. Intuitively, it can be seen that information, although completely reliable, is of limited value to anyone

when it concerns features of alternatives that the traveler does not care about. From the micro-economic perspective used in our model, this means that the individual expects that the utility derived from an alternative will not substantially change after receiving the information. Now this is exactly what might happen when car-drivers are faced with the availability of transit information: this information mostly concerns transit travel times and costs, whereas travelers in general, and car-drivers in particular, appear to find other features of travel modes more important. Such features are often called symbolic characteristics (Steg *et al.*, 2001; Ellaway *et al.*, 2003; Anable & Gatersleben, 2005; Steg, 2005), and include perceived individuality and freedom, image, perceived environmentally friendliness, etc. Other features of travel alternatives such as comfort and convenience, which are difficult to define, also appear to play an important role in a travelers' mode choice process (Kenyon & Lyons, 2003).

Let us examine Figure 2 for a view on the effect of information value among non-habitual car-drivers of the fact that the feature that the traveler is informed about (travel times) may not be highly relevant to them. In other words, the importance of the travel time characteristic relative to all other characteristics is varied, maintaining complete perceived reliability of the information, *ceteris paribus*, from  $\beta = 0.5$  to  $\beta = 1.75$ . It can easily be seen that as the relative importance of other characteristics increases, the perceived value of acquiring information concerning transit's travel time decreases as it refers to a characteristic whose relevance decreases. Furthermore, it can be observed that increases in small values of  $\beta$  have a far more limited impact on perceived information value than the same increases in larger values of  $\beta$ . For relatively large values of  $\beta$ , the perceived information value appear to increase linearly with increasing values of  $\beta$ . To summarize, as car drivers become more interested in characteristics such as image and convenience, they know that travel time information, whether or

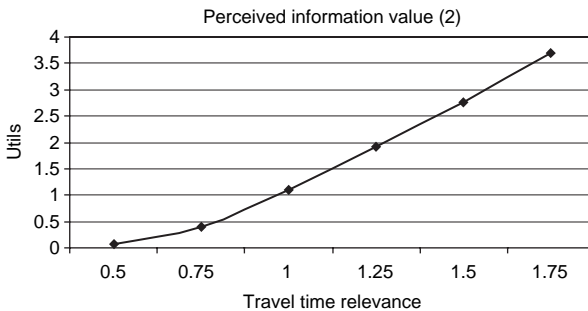


Figure 2. Influence of travel time relevance on information value

not completely reliable, will only have a very limited updating impact on the utility they expect to derive from choosing transit.

Let us now assume the even more unrealistic situation in which the information service is perceived to be completely reliable, and the feature it concerns (transit travel time) is considered to be very important by our car-driver (i.e.  $\beta = 1.75$  in our example). Will this lead to a substantial usage of such information on transit? The conditions of perception and utility updating are met, as the traveler knows that they will take received messages seriously, and that they may substantially update their utility of the transit-alternative based on the update of their travel time perception. One condition remains, however: *updating of mode-choice*. Intuitively, it is clear that when an individual perceives an alternative as being very unattractive in general, the traveler will not expect to derive value from being informed about the alternative's features, even if this information is completely reliable and addresses important features. The reason for this in a micro-economic sense is that the individual knows that even a substantial update in utility of the unfavorable alternative will not make them change their mind – that is, make them update their choice, as other alternatives available will remain more attractive. In the model presented here, this notion is captured through the concept of expected regret: a very unattractive alternative does not cause any expected regret, notwithstanding the uncertainty the traveler faces concerning one or more of its attributes, whether these are important or not. Highly reliable and relevant information will then not be able to make a substantial difference in that situation.

In a mode choice context, exactly this situation appears to apply among conscious car-drivers, as they by definition prefer their car to the transit alternative. More specifically, it appears that those car-drivers that do consider the transit option (non-habitual ones in our terminology) generally consider the potential (Ibrahim, 2003) and the availability (Hague Consulting Group, 1991; De Palma & Rochat, 1999) of transit as being far lower than that of their car, making transit a non-preferable option in their eyes. Applying our model of a non-habitual traveler, we indeed find a strong effect in the difference in base preferences for the two modes on their susceptibility to acquire information on the least preferred mode (transit in our example). Figure 3 shows our model's calculations of the perceived benefit of acquiring information concerning transit, while increasing  $u_{car}^{base}$  from 55 utility points up to 75 utility points, keeping  $u_{trans}^{base}$  constant at 55. For those cases where the intrinsic preference for car over modes is non-existent (i.e. travelers are indifferent between the two modes in general) or small, perceived information value is large. This signals that in those situations, travelers may want to break the tie by looking at the modes'

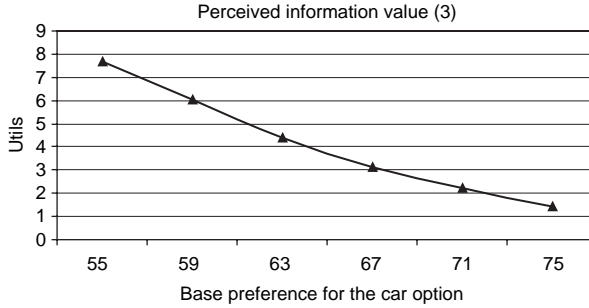


Figure 3. Influence of a base preference for the car on information value

attributes. However, it becomes clear that an increase in differences in base preference for the car option strongly affects a traveler's propensity to acquire transit information: perceived information value decreases exponentially with increasing differences in base preferences. Although the information is completely reliable, and addresses an important feature, the traveler does not expect that they will adapt their choice following the reception of information: the preference gap is simply too big. This argument stresses the role of base preferences and complements empirical literature that suggests that travelers mostly look for information regarding an option they plan to choose in the first place (Polak & Jones, 1993; Srinivisan *et al.*, 1999; Van der Horst & Ettema, 2005).

Summarizing the analyses of this section, it appears that even among those car-drivers that do consider transit as a mode option, the perceived value of acquiring information about the transit option (transit travel time in our example) in real-life mode-choice situations may be severely limited by a number of factors: first, a traveler may feel that the fact that the travel information will generally not be completely reliable will prohibit a full *updating of perception*, especially in those frequent cases where a traveler perceives themselves to be relatively knowledgeable on transit features. Second, they may feel that the fact that the information addresses features (such as travel time and costs) that are surpassed in importance by other non-informable features (such as convenience, status or freedom), will prohibit a substantial *updating of utility* derived from transit. Third, they may feel that the fact that there is a difference in base preference between the transit and car option (which is generally the case for car-drivers) may prohibit an *update of mode-choice*. The analyses thus suggest that even non-habitual car-drivers will often be prepared to bear only very little costs in terms of effort, attention and money for acquiring information about transit.

### Effect of Received Transit Information on Mode-choices: Simulations

Having discussed several issues surrounding the acquisition of transit information among non-habitual car-drivers, let us now examine the potential impact of such information, should it be acquired by them. Table 2, based on equations (7)–(9), followed by (4) and (5), shows the actual computed values referring to figures presented in this section. That is, let us assume that the costs of information acquisition (both in terms of effort and money) are sufficiently low to induce acquisition of transit information among these car-drivers, and investigate the effect of the messages received on their mode-choices, driven by minimization of  $ER_{trans}$  and  $ER_{car}$ . We will use the example from the second section, the settings of which in the base case are as follows:  $\mu_{car} = \mu_{trans} = 50$ ,  $\sigma_{car} = \sigma_{trans} = 10$ ,  $u_{car}^{base} = 65$  and  $u_{trans}^{base} = 55$ ,  $u(tt) = -\beta \cdot (tt)$  with  $\beta_{base} = 1$ , giving  $ER_{car} = 2.14$ . and  $ER_{trans} = 12.02$ . Information unreliability is set  $\sigma_{trans}^{info} = 1$ . *It should be acknowledged that car drivers in general have a too negative perception of transit characteristics, such as transit travel times (Li, 2003; Bonsall et al., 2004).* Let us assume that this is also the case for non-habitual car-drivers, and thus assume that a car-driver acquiring transit travel time information will receive a travel time estimate from the service that is lower than their initial expectations. In our mode-choice example, where the traveler has an initial mean travel time estimate of  $\mu_{car} = \mu_{trans} = 50$ , we assume that they receive the following message: ‘transit travel time equals 38 min’, meaning that their initial estimate for transit’s travel time was 12 min off in favor of the car alternative. Note that we assume here that the individual traveler will always choose the mode that they perceive to have the lowest expected regret. Again, the perspective of updating perceptions, utilities and choices will be used to study the effect of this message on the car-driver’s mode-choice. We will use the same line of argument used in the previous section to identify the roles of several determinants of the effect of information. Starting with the issue of *perception updating*, or relative information reliability, Figure 4 clearly indicates that the favorable message only causes a substantial decrease in expected regret to be derived from the transit option when the car-driver attaches sufficient credibility to the information source, relative to their initial knowledge.

More specifically, any perceived relative unreliability of the service higher than 0.4 (perceived relative information unreliability operationalized as  $\sigma_{PT}^{info} / \sigma_{PT}$ ) will lead to a discounting of the received message to such an extent that the traveler will still prefer their car as travel mode, notwithstanding having received the positive message regarding transit travel time. Only a message that is perceived as being very reliable, compared to the traveler’s initial knowledge, will lead to a

Table 2. Computed values of ER

$ER_{car}$ (upper row) <sup>a</sup> ,			$\beta$						
$ER_{trans}$ (lower row) <sup>a</sup>			0.5	0.75	1	1.25	1.5	1.75	
$u_{car}^{base}$	55	$\sigma_{trans}^{info}$	0	–	–	–	–	–	21.57
									1.06
	59	$\sigma_{trans}^{info}$	0	–	–	–	–	–	18.14
									1.63
	63	$\sigma_{trans}^{info}$	0	–	–	–	–	–	14.96
									2.45
	65	$\sigma_{trans}^{info}$	0	0.61	2.45	4.94	7.66	10.52	13.46
				4.75	3.66	3.22	3.01	2.94	2.95
			2	–	–	4.83	–	–	–
						3.48			
		4	–	–	4.44	–	–	–	
					4.20				
		6	–	–	4.00	–	–	–	
					5.22				
		8	–	–	3.60	–	–	–	
					6.28				
		10	–	–	3.28	–	–	–	
					7.23				
	67	$\sigma_{trans}^{info}$	0	–	–	–	–	–	12.05
									3.54
	71	$\sigma_{trans}^{info}$	0	–	–	–	–	–	9.51
									5.00
	75	$\sigma_{trans}^{info}$	0	–	–	–	–	–	7.31
									6.80

Note: <sup>a</sup>where:  $\mu_{car} = \mu_{trans} = 50$ ,  $\sigma_{car} = \sigma_{trans} = 10$  and  $u_{trans}^{base} = 55$  and travel time message = 40 min

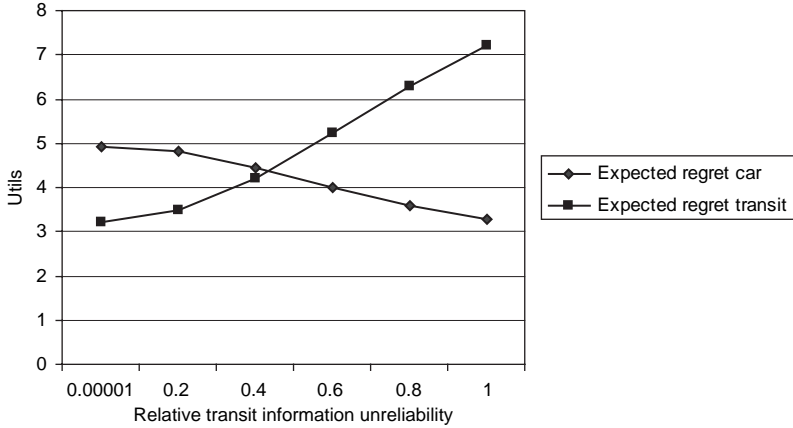


Figure 4. Influence of relative information unreliability on expected regret

change in mode choice. In general, it can be seen that the message’s perceived capability of updating a traveler’s expected regret rapidly decreases once its perceived unreliability exceeds about one third of the traveler’s perception of the unreliability of their own knowledge (being  $\sigma_{PT} = 10$  in our example). Again, the fact that car-drivers find their own knowledge concerning transit-characteristics fairly reliable (Bonsall *et al.*, 2004), in combination with the perceived unreliability of travel information services in general, appears to form a formidable barrier to the impact of transit information on modal split.

Let us now assume the unrealistic situation in which the information service is perceived as being approximately completely reliable, meaning that the traveler’s initial transit travel time perception ( $\mu_{PT} = 50$ ,  $\sigma_{PT} = 10$ ) is replaced with the service’s message that transit travel time equals 40 min. Doing so, we can investigate the issue of *utility updating*, or information relevance, using Figure 5. It is immediately clear that in those cases where the importance attached to travel time (operationalized through parameter  $\beta$ ) is less than some value, in this case approximately 0.875, the message received will not lead to a change in mode-choice, due to the fact that the complete update of travel time perceptions does not lead to a sufficient update in utility to be derived from the transit option as a whole.

In order to investigate the issue of *choice updating*, or the influence of base preferences, let us assume the highly unrealistic situation where the information is perceived as being completely reliable, and travel time is of paramount importance to the traveler ( $\beta = 1.75$ ). Figure 6 indicates that in this situation, where the received message leads to a substantial positive update in the utility of the transit option, a large

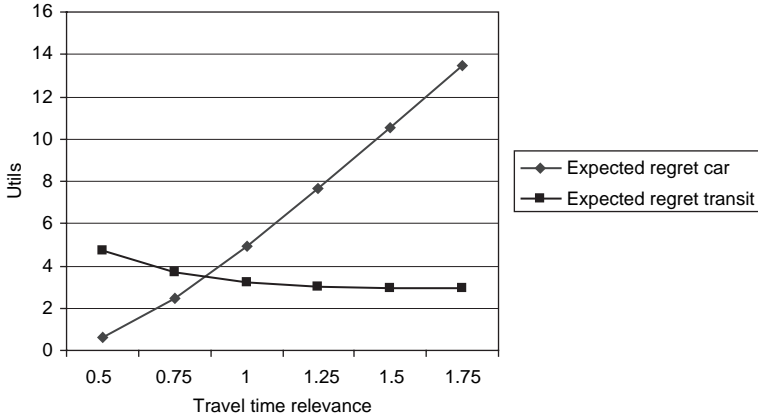


Figure 5. Influence of travel time relevance on the impact of information on expected regret

intrinsic base preference for the car option might still prohibit choice updating.

Summarizing the analyses of this section it can be said that even in those situations where non-habitual car-drivers do acquire information concerning the transit option and receive a message that favors the transit option, the impact of this message on the traveler’s mode choice will still be limited by the same issues arising in real-life mode-choice situations that might prohibit information acquisition in the first place. Perceived relative unreliability of the information source prohibits full *updating of perceptions*, information irrelevance due to the existence of important other utility-drivers than travel times and costs may prohibit

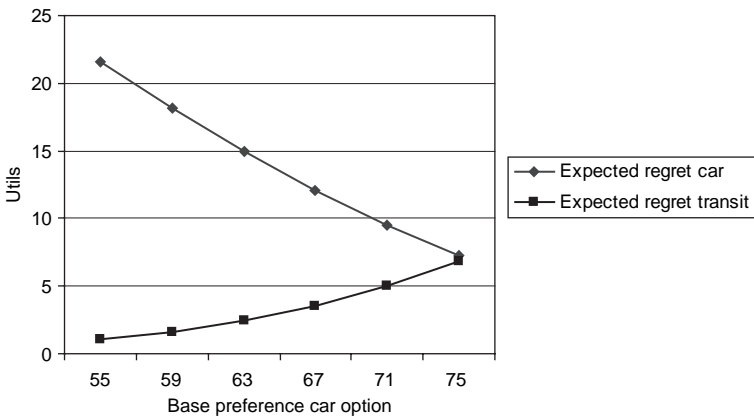


Figure 6. Influence of base preferences on the impact of information on expected regret

substantial *updating of utility* and the fact that there apparently exists a base preference for the car option may prohibit an ultimate *updating of mode-choice* in favor of the transit option. Generally, the effects of these determinants on the expected utility of the informed alternative exhibit a linear trend.

## **Conclusion**

This article has investigated the use and effects of travel information about transit among a group of travelers that is often overlooked in the literature on mode-choices: car-drivers that do consider transit as a mode-choice, but generally prefer traveling by car. Where recent research efforts have empirically investigated issues concerning the actual use and effects of travel information in mode choice contexts, this article added to the existing insights by introducing a theoretical, regret-based model of information use and effects illustrated by examples based on synthetic data. The contribution of this approach is that it allows the systematic and coherent discussion of the working of several complex mechanisms behind information use and effects, and that it allows for the establishment of an upper boundary in information use and effects by explicitly representing non-habitual travelers.

The results show that, even among this group of car-drivers that do consider transit as a potential alternative to their car, the value of acquiring travel information concerning the transit option (in our example travel time information) may be severely affected by three distinct factors: the traveler knows that information unreliability prohibits a full updating of perceptions; information irrelevance prohibits a full updating of transit-utility; and their base preference for the car-option may prohibit a change in mode choice. These trends are mostly non-linear. Furthermore it is identified that even in those situations where travel information is acquired among these car-drivers and the message is highly favorable to the transit option, then exactly the same factors as mentioned above will severely limit the effect of the received information on mode-choice toward transit among the group of conscious car-drivers. Their effect on information appears to follow linear trends. Given these results, obtained for those car-drivers that do consider transit in their choice process, this study suggests that for car-drivers in general, thus including the substantial share of habitual drivers that are not at all inclined to acquire information on other modes' characteristics nor have their mode-choice changed as a result of received messages (Aarts *et al.*, 1997; Verplanken *et al.*, 1997; Lyons, 2001; Gärling *et al.*, 2001, 2002; Kreitz *et al.*, 2002; Kenyon & Lyons, 2003), conservative estimates regarding the effect of transit

information on modal shift towards transit appear to be realistic. This study is thus consistent with conservative estimates (Kanninen, 1996; Kenyon & Lyons, 2003; Fujiwara *et al.*, 2004), rather than with more optimistic views (Abdel-Aty, 1996, 2001; Ouwersloot *et al.*, 1997, Reed *et al.*, 1997).

What may be learned from these results with respect to the design of transit information services? First, the minimization of costs of information acquisition seems to be a necessary condition for their use among non-transit travelers. This should be interpreted from an 'all costs' perspective: it seems that only transit information that is provided for free, and that is very easily accessible, has any chance of being often used among car-drivers. Second, it appears that information reliability is also of paramount importance: if very reliable transit information appears unattainable, then its use and effect among car-drivers will be severely limited. This signals firmly the need for dynamic, rather than static, travel information on transit options. The information should furthermore also refer to aspects of comfort, convenience and perhaps environmental friendliness of the transit option, as the traveler might place importance on such attributes. Such low-cost, high-quality information might be used by a non-habitual car-driver and, when used, might have an effect on their mode-choices, but only when their base preference for the car option is limited, and attractive transit-alternatives to their private car are available. In all other cases, however, it seems more efficient and effective to inform car-drivers about their car's limited attractiveness in some situations (e.g. large travel time increases due to bad weather or accidents): such information has a much higher chance of actually being acquired and used in the car-drivers mode-choice process.

Finally, it can be concluded that the proposed regret-based model of information acquisition and effects provides insightful results that are at the same time consistent with empirical literature on the topic. It complements earlier empirical findings concerning the topic as it appears to offer a structured way of discussing the use and effects of information, especially in those situations where deliberate choices are made. We would encourage further regret-based applications in travel behavior literature, as they promise to provide realistic accounts of travelers' behavior under uncertainty. Currently, validation and estimation of the model is taking place, based on empirical data that is obtained in an interactive travel environment (Chorus *et al.*, 2006c). This will make possible even more rigorous investigations of the determinants of travel information use and effects.

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